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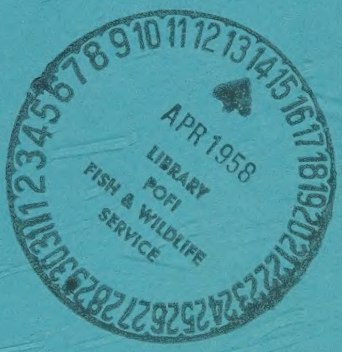

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Minister of Fisheries

The Importance of Size in the Change from Parr to Smolt in Atlantic Salmon

by

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The factors associated with the metamorphosis of young Atlantic salmon from river-dwelling parr to seaward-migrating smolts have not been very well defined. Size has been regarded as an important factor by some investigators and relegated to a minor position by others. Pyefinch (1955) gives a useful review of literature on the subject of this change from parr to smolt. Svardson (1955) suggested a set of hypotheses involving "physiological age" of the individual fish in combination with environmental considerations. Most investigators have concentrated their attention on the young salmon near or during the immediate season of migration. Vibert (1950), however, offered evidence that age at migration had been set by the end of the first winter of river life.

Salmon production of the Miramichi River system, in New Brunswick, has been investigated by the Fisheries Research Board of Canada for the past seven years. Part of the program calls for knowledge of the numbers of smolts produced. Direct counts have not been attempted in the larger tributaries because log drives prevent weir operations during part of the run. Indirect estimates are consequently necessary. These rely upon a combination of seining and electrofishing done late in the summer. In the Miramichi system approximately one-third of the smolts migrate as two-year-olds and two-thirds as three-year-olds. Observations by Canadian investigators indicate that size, or physiological condition associated with size, of parr in their pre-smolt year seems to be a more important factor than age in the change from parr to smolt. As a working approximation an arbitrary dividing line between large parr, likely to become smolts next spring and small parr, not likely to, has been set at about 10 cm. or 4 in. total length, measured from tip of snout to tip of tail. From the facts assembled here it appears that there is justification for using this convenient rule of thumb.

Evidence from hatchery yearlings

In mid-June, 1945, hatchery-reared yearling Atlantic salmon of sea-run, and of lake, or landlocked, stocks were being planted in the Rawdon River, Grand (Schubenacadie) Lake system of Nova Scotia. It was observed that the larger fish of both stocks had a heavy, silvery coating of guanin on their scales, much more than is normal for river-dwelling parr of comparable size. Other smolt characteristics such as low condition factor and easily loosened scales were apparent to a minor degree. Enquiry to the Department of Fisheries revealed that all the fish "had been fed (chopped) plucks and fish through January to the time of examination (June 16), except that they

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were fed fish only during the second and fifth weeks of May. It is quite possible that the thyroid gland was included in the plucks which were fed.....". Hoar (1939) has shown that the change from parr to smolt stage, which he terms a true metamorphosis, is associated with greatly increased activity of the thyroid gland. Robertson (1949) showed that in large (9 to 10 inches) two-year-old rainbow trout (*Salmo gairdneri*) the silvery smolt stage could be induced by intra-muscular injection of mammalian thyroid extract. Hoar (personal communication) has expressed his opinion that "certainly fresh thyroid gland in the food supply should tend to initiate a smolt transformation".

At the time of the observations above, approximately 300 fish from each stock were taken at random from the supplies in the hatchery's holding ponds. Each fish was classified according to the extent of its silvery colour as "parr", or "smolt". The fish were measured and mean lengths were calculated for each of the categories in both stocks. For both kinds of salmon there was a fairly clear-cut division into large, silvery "smolts" and into smaller "parr" without obvious silvery colour. These size groupings are shown in Figure 1. There was some overlapping of sizes between parr and smolts but there was no silvery coloration on fish of sea-run stock under about $11\frac{1}{2}$ cm. or on lake stock under about $10\frac{1}{2}$ cm. long.

Comparison between sea-run and lake salmon is shown in Table I.

Table I.

Lengths (cm.) of yearling salmon of sea-run stock and of lake stock, from the Schubenacadie Grand Lake Rearing Ponds, Nova Scotia. (Measured June 16, 1945.)

	Parr			Smolts		
	Number Specimens	Mean Length	Standard Deviation	Number Specimens	Mean Length	Standard Deviation
Sea-run	264	10.2	±1.0	65	14.2	±1.3
Lake	238	9.7	±1.4	52	13.8	±1.5

The difference in size of the two stocks seems largely attributable to the lake salmon growing more slowly than the Atlantic salmon. In keeping with this a slightly smaller proportion of lake salmon (18%) than of sea-run salmon (20%) showed the change from parr to smolt. Wilder (1947) also found relatively slow growth to be a characteristic of lake salmon.

The data show that both the sea-run and lake salmon stocks conformed to a general size characteristic in relation to the incidence of guanin deposition. The evidence does not show that the fish became smolts at a specific size of about 10 cm. Rather it shows that, for both stocks, only those fish which had already reached 10 cm. were subject to the change from parr to smolt.

This evidence of a size prerequisite for transformation of hatchery-reared fish should be useful to fish culturists in planning salmon-rearing programs for particular purposes. For example, in a stream where smolts are typically three years old, fingerlings planted in one summer would be expected to produce a smolt run three years

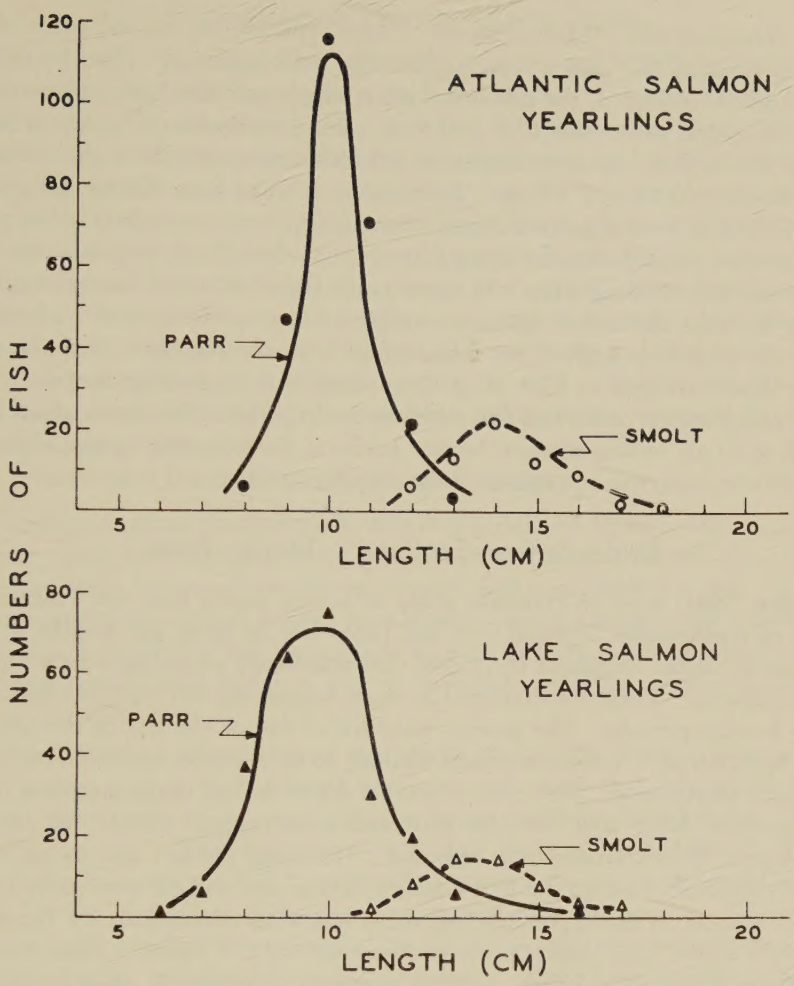

Figure 1.—Length-frequency distribution of hatchery-reared yearling salmon of Atlantic and lake stocks, classified as parr having no obvious silvery guanin deposit on the scales, and smolts having a heavy guanin deposit. Only fish over 11½ cm. (Atlantic) and over 10½ cm. (lake) showed this smolt characteristic. (Fish examined at Grand Lake Rearing Ponds, N.S., June 16, 1945)

later; planting small parr should yield a run only two years after planting, and planting large parr one year after. Liberating smolts directly from the hatchery is proving worth while for one Swedish river from which salmon have been excluded by a dam (Carlin, 1955). Programmes using hatchery-reared smolts might benefit by consideration of such a size prerequisite. This subject is now being examined through experimental plantings.

Evidence from Pollett River Smolts

During the course of experiments involving Atlantic salmon smolt production from the Pollett River, Petitcodiac River system, New Brunswick, scales from several thousand smolts were examined. For the most part age determinations only were made. Here, 90 to 95 per cent of the smolts run as two-year-olds, and almost all the

rest as three-year-olds. Measurements of scale radii for the several years of river life were made on 250 typical samples from the 1950 smolt run. For the 14 three-year-old smolts measured, the calculated mean length and standard deviation at the end of the second winter was 10.7 ± 0.8 cm. For a representative group of 22 two-year-old smolts from the same migration, calculated mean length at the end of the second winter was 14.0 ± 1.7 cm. Examination of scales from Pollett parr collected monthly through most of a year indicated that usually about one-quarter of the growth for the year occurred during the laying down of the winter band, between about Mid-August and the following May. In consequence most fish which were about 11 cm. long by the time the winter band was completed were probably well under 10 cm. long in the preceding August: but those which were around 14 cm. long, or longer, in May must have been at least 11 or 12 cm. long in the preceding August. These Pollett young salmon conformed fairly well to the hypothesis that those which exceed a length of 10 cm. by late summer, become smolts in the following spring; while those which do not attain this size remain in the river for an additional year or more.

Evidence from Scotland—Thurso River

Allen (1944) made an extensive study of salmon smolts from the Thurso River system of northeastern Scotland. In his Table VII he gives the lengths at smolt stage and calculated lengths at the end of the immediately preceding winter for 1,317 two-year-smolts. These are expressed as mean lengths for fish captured during successive five-day periods. The general mean for all fish at the end of the preceding winter was 10.6 cm. Only two groups totalling 50 fish, or 4 per cent of the collection, had a mean length under 10 cm.; and it was 9.5 cm. at the end of the preceding winter. Unfortunately Allen does not give first- and second-winter lengths for the small percentage of three-year smolts he recorded. However, the fact that 96 per cent of his two-year smolts reached the 10 cm. length at this time, and the rest nearly attained it, gives support to the hypothesis that there was a size prerequisite for the change, which was of the same general order as that observed in Canada. Allen concluded that "there is no critical length at which migration takes place". But he concurred with earlier authors, that "parr must attain some physiological condition associated, at least as an index, with a minimum size before the smolt migration takes place". The hypothesis that this condition is associated with a length requirement of about 10 cm. during the latter part of the pre-smolt year of growth, is not at variance with the conclusions drawn by Allen.

Evidence from England—The Cheshire Dee

Jones (1949-Appendix, Table II) gives the calculated yearly lengths of 335 smolts taken from the River Dee, Cheshire, in 1938 and 1939. He had one-, two- and three-year smolts. Nearly 92 per cent of these fish satisfy the present hypothesis. Dee smolts which did not conform were those migrating at 1+ years. But even these had all made rapid growth during the first season—$7\frac{1}{2}$ to $9\frac{1}{2}$ cm. against $4\frac{1}{2}$ to 5 cm. Rapid spring growth in the season of descent brought them to about $12\frac{1}{2}$ cm. Since a large majority of the fish conform, the 10-cm. hypothesis should be useful in studying late summer parr populations in such a stream.

Evidence from France—River Adour

Vibert (1950) gives calculated mean lengths at the end of each year of river-life for 492 smolts and 1,022 virgin salmon, in his Table XIV. Nearly all the fish conformed in that they did not migrate if they had not reached the 10-cm. length, but migrated in the next spring, after reaching or exceeding an approximate 10-cm. length towards the end of a growing season. One three-year smolt reached a length of 11 cm. at the end of its second year, as did one of Jones' three-year smolts from the River Dee. Since the 10-cm. hypothesis is based on mean lengths in late summer rather than the length of individual fish at the end of a year's growth these do not constitute exceptions. Among Vibert's virgin salmon, a group of 11 which had been three-year smolts had a calculated mean length of 13.6 cm. at the end of their second year of river life but still spent one additional year in the river. The fact that 99 per cent of his fish conformed to the 10-cm. hypothesis indicates that it would be a useful working rule here also.

Discussion and Summary

Evidence is presented from both sides of the Atlantic to show that, as a general rule, parr which have reached or exceeded a certain size towards the end of one growing season are likely to become smolts at the next season of smolt descent. A similar size prerequisite also appears to hold for a slower-growing Canadian lake salmon stock. In fact, the concept of a size prerequisite appears to have more fundamental significance with respect to change from parr to smolt than either age or size at the actual time of transformation.

The hypothesis definitely does not specify that young Atlantic salmon become smolts as soon as they reach a length of 10 cm., but rather that they transform after reaching this length in the smolt-running season immediately following. Growth of parr is variable. Those which have nearly but not quite reached the 10-cm. length at the end of a summer will, if they grow fast, reach a much greater length, say 14 to 16 cm., at the end of the following summer, and make big smolts. Those which have just barely attained the required 10 cm. size at the right time will, if slow-growing, make little smolts, perhaps only about 12 cm. long. The 10-cm. hypothesis thus takes account of the extremely variable size-range of smolts from many types of rivers.

Some individuals destined to become older smolts may exceed this length, but seldom by more than two or three cm., at the end of their second last season of river growth. A few fish may not quite reach this size but still become smolts during the following spring if they grow fast and exceed the 10-cm. length during the smolt-running season. While not precise for individual fish, this 10-cm. hypothesis provides a useful and justifiable rule of thumb for gauging annual smolt production from streams.

Canadian investigators of Atlantic salmon at present classify young salmon as "small" parr, those which will probably spend one or more additional years in river growth, and "large" or "pre-smolt" parr, those which are likely to descend as smolts during the next seaward migration. The arbitrary division between the two groups of parr has been chosen at a total length of 10 cm. or 4 in. reached during the latter part of a year's growth.

Use of the hypothesis should contribute to effective planning of salmon-rearing programs for hatcheries, if special purposes can be served by planting larger fish.

Acknowledgments

The Grand Lake salmon were examined while assisting Dr. A. G. Huntsman in his investigations there; he kindly made time available for the observations on hatchery stocks. Mr. William Cameron, Superintendent of the Grand Lake Rearing Ponds, assisted in handling these yearling salmon. Mr. W. G. Carson of this Station made the scale measurements for Pollett smolts while reading some 2,000 smolt scale samples from this stream. I thank these gentlemen for their help.

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Using Hatchery-Reared Atlantic Salmon to Best Advantage

by

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Good management of Atlantic salmon requires knowledge of how to get the best production of seaward-migrating smolts. This applies whether the stocking be through natural means or through the introduction of hatchery-reared stock. The Fisheries Research Board of Canada has, for a number of years, been investigating factors associated with the production of smolts from hatchery-reared stock. This is a preliminary survey of the results which can be found in condensed form at the end of the paper.

Much of the following discussion will refer to numbers which can be produced, must be planted and so on. To use total numbers from experiments would have no significance for other areas than the one in which studies were made. Hence, important figures have been converted to easily imagined units. For general use the average number per 100 square yards has been selected—an area 30 feet by 30 feet, or about the size of an average house. Sometimes it is more convenient to think in terms of the length and width of a stream. For this a unit of one mile of stream 10 yards wide (176 of the square units) has been selected. The 100 square yard unit will be meant unless otherwise stated.

1. PREDATION BY MERGANSERS SHOULD BE LIMITED

Several years ago White (1939) found that a stream stocked with native salmon gave more smolts when mergansers (*Mergus merganser americanus*) and kingfishers (*Megaceryle alcyon alcyon*) were kept away. A study has recently been completed on the effect of similar bird control in increasing the smolt yield from hatchery-reared fish. Experiments were done on a 10-mile stretch of the Pollett River, a tributary of the Peditcodiac system in southeastern New Brunswick. Table I shows the total number of two- and three-year-old smolts produced from seven different plantings of underyearling salmon. Two of the plantings were quite light; five were fairly heavy. However, as will be shown in Section 2, below, even the light plantings should have experienced a better survival rate than they did. If judged solely on a comparison of the results from the heavy plantings, there was an increase of about four times with birds kept away. If judged on the average "before and after" figures, by nearly seven times.

Table I also shows the estimated number of parr in the river, midway between planting and smolt descent. It is on these parr that the birds do most of their feeding.

Table I

Smolt production from known plantings of hatchery-reared underyearling salmon in the 10-mile experimental area (approximately 435,000 sq. yd.) of the Pollett River, N.B.

	Year of planting	Number of underyearlings planted (nearest 5,000)	Resulting parr 1 year after planting (nearest 5,000)	Resulting 2- and 3-year smolts (nearest 1,000)
With no bird control	1942	15,000	under 5,000	2,000
	1943	15,000	under 5,000	1,000
	1945	250,000	10,000	5,000
Average	.....	over 15,000	5,000	3,000
With control of mergansers and kingfishers	1947	275,000	25,000	22,000
	1948	235,000	45,000	14,000
	1949	245,000	40,000	19,000
	1950	245,000	55,000	24,000
Average	.....	250,000	40,000	20,000

Records were kept of all birds seen. The food recently eaten by many of those shot was studied. In Table II estimates are given of the number of fish which the birds could have eaten had there been no control. There are also estimates of the numbers that could have been eaten by those birds which escaped the patrols. Without control, enough mergansers visited the area to eat more parr than the river could support. But with control the remaining mergansers could take only about one quarter of the parr when there was a good parr crop. This is not enough to seriously affect the smolt-producing capabilities of the stream.

Table II

Estimated numbers of fish which visiting mergansers and kingfishers could eat annually while on the 10-mile experimental area of the Pollett River.

	Mergansers		Kingfishers	
	All fish	Young salmon	All fish	Young salmon
Without Control	180,000	75,000	120,000	10,000
With control	20,000	10,000	10,000	1,000

Year-to-year records showed that when parr were more abundant, more mergansers came to the area. They came any time of the year that there was open water on the river (Fig. 1).

In general, the rate of production when mergansers had free reign was about one smolt per 100 square yards of stream. With bird control, production jumped to a rate of five to six smolts per 100 square yards.

Figure 1.—Mergansers on a New Brunswick salmon stream in mid-winter.

Surveys have shown that mergansers are as abundant on many Maritime streams as they were on the Pollett. But they are furtive birds and their abundance can easily be underestimated. To get the best results from hatchery-reared stock, or native stock too, for that matter, mergansers should not be more abundant than about one bird for every 10 to 15 miles length and 10 yards width of stream.

Kingfishers, as shown in Table II, could not remove enough young salmon to seriously affect the smolt output unless the birds were to increase greatly in numbers. Their habits make them conspicuous along a stream. Because of this, in contrast to mergansers, it is very easy to overestimate their abundance and their importance to salmon. It is doubtful that the results of controlling kingfishers along most salmon streams would warrant the trouble and expense. However, if they were more abundant than two for every mile length and 10 yards width of stream, control might be worth while.

2. HOW MANY FISH SHOULD BE PLANTED?

To know how many fish to plant it is first necessary to know how many smolts an area can produce.

Smolt producing capacity of streams. The bird control studies mentioned above showed that the 10-mile stretch of the Pollett could produce smolts at a rate of about one per 100 square yards without bird control; but five with control. This was from

planting fingerlings at rates of 55 to 60 per 100 square yards. To find out whether planting more fingerlings would give more smolts a planting was made at the rate of 213 fingerlings per unit area—about four times as many. Data are given in the two top rows of Table III. Smolts were produced at the rate of six per unit area. This is not sufficiently different from five smolts to be regarded as anything more than the difference between years with favourable or unfavourable conditions for survival. That is to say, the maximum capacity with bird control can be set at five to six smolts per 100 square yards.

Table III

Smolt production and survival rates from heavy, medium and light plantings of underyearlings and one small accidental spawning in a 10-mile stretch of the Pollett River, N.B. Total experimental area = 435,000 sq. yd. (a) Accidental spawning resulted when exceptionally high freshet brought a few adult salmon past a closed fishway into the experimental area. (b) "Best survival rate" from planting to parr was approximately 25%. (c) "Best survival rate" from parr to smolts averaged approximately 65%.

Number of underyearlings planted		One-year parr per 100 sq. yd.	Survival rate underyearlings to parr %	Two-year smolts		Survival rate parr to smolts %
total	per 100 sq. yd.			per 100 sq. yd.	total no.	
925,000	213	16	8	6	23,750	34
240,000	55	15	27(b)	5	22,852	35
65,000	15	4	27(b)	2	8,052	51(c)
accidental(a)	—	over 1	—	under 1	3,556	80(c)

Observations on young salmon in Miramichi streams (Elson, 1957a) indicate that the smolt producing capacity of these streams, both without and with bird control, is similar to that found for the Pollett. A relatively infertile stream in the Gaspé peninsula of Quebec, the Port Daniel River, also gives smolts at the approximate rate of one per 100 square yards; not enough mergansers visit this stream to warrant their control.

Survival rates from fingerlings to smolts. The plantings which gave maximum smolt production may have wasted quite a few fry. In fact, compared with results of the planting made at a rate of 55 fry, planting 213 fry did waste about three quarters of the fish. To discover the "best survival rate" when no such wastage was involved, a planting was made at about one quarter of the first rate (actually, 15 fry per 100 square yards). This and other measurements of "best survival rate" from sparse populations, which means no unnecessary wastage, are given in the last two lines of Table III. The best survival rates from fry to yearlings were a bit over 25 per cent. The best survival rates from sparse parr populations to smolts averaged 65 per cent. This gives over 16 per cent as the survival rate from fry to smolts. To play safe the general rate from late summer fingerlings to two-year smolts should be 15 per cent.

Although the smolt capacity of Miramichi streams is apparenly about the same as the Pollett, there is one important difference. Where nine out of 10 Pollett smolts are two years old, seven out of 10 Miramichi smolts are three-year-olds. This means Miramichi parr must go through an extra year in the river, during which there is some

mortality. Here again the observations in the Miramichi area indicate that the survival rate over this extra year is of the same general order as the rate over the last year on the Pollett, i.e., about 65 per cent. So the survival rate for three-year smolts from late summer plantings of fry should be set at only 10 per cent.

It would be useful to know from which streams to expect three-year smolts and which streams two-year-olds. Smolt age appears to be clearly associated with water temperature. In general, warm streams, say over about 68° F. (20° C.) in summer give two-year smolts. Cool streams, say 60° F. to 65° F. give three-year smolts. In still colder, or in very infertile streams, smolt age may be increased to four, five or even eight years; but smolts this old are uncommon in the Maritimes.

Number to plant. The best number to plant is that which will give the full capacity of smolts, while giving the highest survival rate from the planted fish. Approximate figures for the largest numbers of fingerlings it would be worth while to plant are:

In fertile streams with mergansers less than one per 10 miles × 10 yd. of stream.

for two-year smolts	7,000 fingerlings per mile × 10 yd. wide
for three-year smolts	10,000 fingerlings per mile × 10 yd. wide

In barren streams, or fertile streams with mergansers more abundant.

for two-year smolts	2,500 fingerlings per mile × 10 yd. wide
for three-year smolts	3,500 fingerlings per mile × 10 yd. wide

These are the highest figures. In most years planting 1,000 or so less should give nearly all the smolts the stream could raise. But planting many more is almost certain to result in waste of all the excess either through predation or starvation.

3. AMOUNT OF DISPERSAL AT PLANTING.

There are two aspects to this: the amount of scattering at chosen planting sites; and the distance between planting sites.

Dispersal at planting sites. The best amount of dispersal at planting received study on a section of the Pollett 10 miles above the area used for the studies of smolt production already mentioned. Three different degrees of dispersal were tested at each of three similar planting sites located two miles apart. The fish planted in each area were distinctively marked by removal of certain fins. Three years was required to complete the planting schedule. The results were measured by counting the smolts from each planting as they passed through the smolt trap 15 miles downriver (Table IV).

The final results indicate that the different degrees of dispersal had no appreciable effect on the number of smolts produced. The difference in the various smolt runs (Table IV) proves on analysis to be largely the result of good and bad years. Further, the bad years were years when mergansers were relatively abundant. No bird control, other than removal of merganser broods, was employed for these dispersal experiments. The important conclusion from this study is that nothing would appear to be gained

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Table IV

Smolts produced from plantings of 4,000 underyearling salmon given different amounts of dispersal at liberation.

Dispersal at planting, as nos. per 100 sq. yd.	Number of smolts produced			
	from 1948 plantings	from 1949 plantings	from 1950 plantings	from all 3 plantings
50	1,183	1,911	618	3,712
500	1,329	1,407	868	3,604
5,000	767	1 793	972	3,532
Total smolts from plantings of 1 year	3,279	5,111	2,458	10,848

by scattering underyearlings, at planting, more widely than at a rate of 5,000 per 100 square yards at each planting site. A similar study of dispersal rates for yearlings is just being started.

Distance between planting sites. The natural spreading of the young fish away from their points of liberation was followed in several of the planting experiments mentioned above. The general picture was that the surviving fish spread fairly uniformly over the stream for about one-half mile up- and one mile downstream in one to two months' time. A year after planting they were fairly well scattered over one mile up- and downstream. A few fish travelled several miles farther than this. But the intervening stream was clearly not being fully utilized. Such lack of utilization did apply to an area two miles below the lowest liberation site through all the years of extensive planting for bird control and smolt capacity studies.

It is therefore concluded that to get full utilization of a stream's resources planting sites should, ideally, not be over two miles apart. However, access for hatchery trucks will often make this impractical; in that event some, if not full use will be made of intervening areas, even if they be several miles long.

4. SIZE OF FISH TO PLANT.

Until recently most hatchery plantings of Atlantic salmon in Canada have liberated fingerlings around $1\frac{1}{2}$–2 inches long. By holding the fish a year they can be grown to 3–6 inches long. Rearing large fish is more costly than rearing underyearlings. When is the extra expense warranted?

A common reason for planting larger fish is the hope that they may be able to escape enemies better than small fish. Consider, however, streams where mergansers are the chief enemy. Mergansers usually take parr from about three inches upwards, but seldom take two-inch fish if larger are available. In such streams newly-planted parr may not be competent in avoiding their new enemies. But their brothers planted as much smaller fingerlings are well adjusted to life in streams by the time they reach this size. Newly-planted fish face not only predators, but also competition with native fish of their own kind. As shown by Miller (1953) for a related species (*Salmo*

clarki) of the west coast this and the strain of adjustment to a new habitat may reduce survival to as low as 0 per cent–3 per cent, even for fish larger than any salmon parr.

The results of some small-scale experiments on yearlings planted in two streams of the Petitcodiac River system in New Brunswick are informative. Holmes Brook and Bennett Brook are each about five miles long and are from two to five yards wide. Both have small populations of native salmon (about two per 100 sq. yd.). In the Holmes Brook more than half the native salmon migrated as three-year smolts, the rest as two-year-olds. Practically all Bennett smolts were two-year-olds. Other fish present in both streams were eels, horned dace (*Semotilus atromaculatus*), Lake Northern chub (*Couesius plumbeus*), black-nosed dace (*Rhinichthys atratulus*) and brook trout (*Salvelinus fontinalis*) which are fished by local anglers. Occasional kingfishers visited the streams, but mergansers seldom if ever. Thus, the two brooks offered conditions similar to those on many Maritime salmon streams when mergansers are not abundant.

The hatchery yearlings, averaging about 10 cm. (4 in.) long, measured from tip of snout to end of tail, were divided into a number of small groups, some of which were of ordinary sea-run stock and some lake stock. Each lot was distinctively fin-clipped before planting. No differences in behaviour or survival value of the two stocks was noted. But considering the differently-marked groups as comprising different experiments adds to the value of the final result. All those surviving to smolt stage migrated the year after planting, as two-year-olds. This applied in both brooks. The results are given in Table V. They may be summed up, in the

Table V

Smolt production and survival rates from July plantings of hatchery-reared one-year-old Atlantic salmon parr in tributaries of the Petitcodiac River, N.B. (In 1945 both Atlantic and Lake salmon were planted in about equal numbers: in 1946 only Atlantic salmon.)

Date and place of planting.

Year	Brook	Miles above smolt trap	Number planted	Number of smolts	Survival rate %
1945	Holmes	1	26 (Atlantic)	12	23
		$2\frac{1}{4}$	26 "		
		1	26 (Lake)	13	25
		$2\frac{1}{4}$	26 "		
1945	Bennett	$\frac{1}{4}$	24 (Atlantic)	1	4
		3	26 "	5	19
		5	26 "	4	15
		$\frac{1}{4}$	31 (Lake)	4	13
		3	25 "	1	4
		5	26 "	3	12
1946	Bennett	$\frac{1}{4}$	50 (Atlantic)	15	30
		2	150 "	22	15
		3	117 "	8	7
		$4\frac{1}{2}$	53 "	1	2
		5	50 "	1	2
	Total		682 1-year parr	90 2-year smolts	

Mean survival rate and its standard error.....13 ± 3%

statement that it is unlikely that similar plantings of yearling parr would experience an average survival rate of less than 5 per cent or more than 20 per cent.

This is not materially better than the 15 per cent survival rate which can be obtained from underyearlings (see Section 2). But the yearlings yielded smolts one and two years earlier than underyearlings would have. On the basis of these data we must conclude that if the object of planting young salmon is merely *to obtain the greatest number of smolts*, then *proper numbers of underyearlings should be planted.* Whether a similar result would apply if such predacious fish as white perch, yellow perch, and fallfish (*Semotilus corporalis*) were abundant, as they are in some salmon streams, has not been investigated. Another conclusion is that *if the object is to obtain smolts as soon as possible, then larger parr should be planted.*

By properly selecting the fish it should be possible, in a three-year smolt stream to reinforce smolt runs occurring any time between planting and three-years later as desired. In order to become smolts, parr must, as a rule, reach a length of about 10 cm. (4 in.) some months before the spring period of smolt migration (Elson, 1957b). Thus, as happened in Holmes Brook, yearling fish which will reach this length in the year of planting will make two-year smolts the next spring, even though the normal smolt age for the stream is three years. Fish which will reach only eight or nine cm. in the year of planting should make smolts two seasons later.

Hatcheries rear some young salmon to smolt stage as yearlings. Will they migrate to sea immediately, if liberated? Hoar (1939) found that the change to smolt stage was associated with increased activity of the thyroid gland. But he also found that if smolts were forced to remain in fresh water after the normal migration period this gland tended to revert to the parr condition. The migratory urge may be lost. This is indicated by the behaviour of some of the yearling fish planted in Bennett Brook in July, 1946. Among the 420 fish liberated, 16 per cent appeared to be smolts, similar to the condition Elson (1957b) reported for other hatchery yearlings. None of these Bennett fish was taken in the smolt counting weir below, in the year of planting. Several were recognized living near their original planting sites, during the summer. Occasional post-smolts which failed to get to sea have been observed in other places. They appeared to be slowly reverting to characteristic parr appearance and behaviour. Hence it would appear advisable to liberate hatchery-reared smolts early in the spring —say in May—if advantage is to be taken of their migratory urge.

Occasions may occur when the expense of planting larger fish than normal underyearlings would be warranted. The recent decimation of Miramichi young salmon by spraying of DDT has been reported by Kerswill and Elson (1955). Plantings of assorted sizes of young salmon could properly reinforce the various year-classes. But these authors found that more large fish survived the spraying than small. It may be necessary that planted fish be subjected to spraying in order to preserve the forests. If so, it would seem advisable to plant them at the largest size reasonably possible. Spraying gives rise to one situation where *only* large fish could remedy some of the deficiencies.

5. TYPES OF BOTTOM FOR PLANTING.

In the experimental plantings described, most fingerlings were liberated in water less than one foot deep, usually in rapids. Studies of the distribution of native young salmon have shown that this is the kind of habitat they prefer. It would be incurring unnecessary risk to liberate such small fish, not yet adapted to the rigours of life in streams, in pools where larger trout or other fish could readily gobble them up. Equally hazardous are areas with large cobble and rocks where eels are abundant. In the Pollett plantings, eels from about a foot upwards in length, were found to take many fingerlings within a few hours of planting in such areas.

6. EELS AS A LIMITING FACTOR FOR SURVIVAL OF UNDERYEARLINGS.

Various observations made during earlier studies, as well as the Pollett experiments, have led to the belief that eels may sometimes limit survival between fry and parr stages. The dispersal experiments described in Section 2 were carried out above the 15-foot drop of Gordon Falls. The falls is a partial barrier to eels, there being one-third as many of the sizes that eat salmon above as compared to below. Up here over 45 per cent survival to smolt stage was reached in one case, the average for the nine plantings being 30 per cent (Table III). On the lower, main experimental area, with an abundant eel population, the comparable survival rate to smolt stage was only 15 per cent. Note that this concerns survival rates from sparse populations. The bird control experiment showed that mergansers act as a limiting factor *after* eels have done their damage. Hence control of the birds is of first importance.

Studies of eels in several New Brunswick streams indicate that they are abundant in streams flowing into the Bay of Fundy, e.g. the Pollett and several tributaries of the St John (Godfrey, 1956) but that in Gulf of St. Lawrence drainages, as represented by the Miramichi River, also Ellerslie Brook in P.E.I., eel populations in the salmon-growing reaches are relatively unimportant. Higher yields of salmon, because of better survival rates, might be expected from both hatchery and native stocks where eels are scarcer, providing predation on older parr and smolts, as by mergansers, is not the limiting factor. So far no practical way of controlling eels has been devised.

7. VALUE OF ADULTS DERIVED FROM HATCHERY STOCK.

Returns to the Pollett River of mature salmon derived from stocks collected in other rivers but planted as underyearlings in the Pollett have been almost negligible. These planted fish have contributed to distant commercial fisheries; but were not identified in any river where close inspection of the stock was maintained. At present a test is under way involving the returns from 800 marked smolts of Pollett stock, reared to the usual underyearling stage in a hatchery, then planted back in the Pollett.

Summary

This summary is given in the form of brief, if somewhat categorical statements, for convenient use of the practising salmon-culturist. The statements should certainly not be regarded as the "final word" on subjects which are still under investigation. But they do have more background of observed facts than has been generally available.

(1) *Control of mergansers.* Best production of smolts from plantings of hatchery-reared Atlantic salmon, or from native salmon should only be expected if mergansers do not exceed an abundance of one bird for every 10 to 15 miles and 10 yards width of stream. Control of kingfishers is of minor importance compared to control of mergansers; kingfishers may be tolerated up to, but not above, an abundance of two per mile × 10 yards width of stream.

(2) *Numbers to plant.* For streams on which mergansers will not greatly exceed the figure of one per 10 miles × 10 yards width, and which flow through geologically fertile areas the maximum number of smolts likely to be produced is around 1,000 per mile of stream 10 yards wide. To get this number of smolts about 7,000 underyearlings should be planted, per similar area, in streams with mostly two-year smolts and about 10,000 in streams with mostly three-year smolts.

For streams with no bird control or those in geologically infertile areas, e.g. flowing largely through granite country, these figures should be reduced to about 2,500 and 3,500 fish for a maximum expectancy of 400 smolts.

(3) *Amount of dispersal at planting.* When liberating underyearling salmon at planting sites, nothing is gained by scattering them more widely than at a rate of 5,000 fish in an area of 100 square yards. Given this start, as many will survive as if they had been dispersed more widely.

Planted underyearlings will move, in good numbers, about one mile up- and downstream from planting stations. So stations should ideally be about two miles apart. But some fish will disperse to as much as several miles away, so that partial use of intervening water will be made even if stations must be farther apart.

(4) *Size of fish to plant.* Where the object is simply to obtain smolts, underyearlings will give as good results as larger parr.

But by using appropriate sizes of parr, smolt runs can be produced earlier than with underyearlings. For example, in a typically three-year smolt stream:

(a) underyearlings will yield smolts three years after planting:

(b) parr which will reach a length of eight or nine cm. in the year of planting should produce smolts two years after:

(c) parr which will exceed a length of 10 cm. in the year of planting should produce smolts one year after:

(d) smolts planted from early spring until late in May might well migrate to sea shortly after being liberated but smolts planted in streams after June seem unlikely to descend in numbers until the following year.

Since underyearlings are very susceptible to DDT poisining and larger parr less so, the size of fish to be used for rehabilitating streams in DDT-sprayed areas should receive consideration.

(5) *Type of bottom for planting stations.* It would seem advisable, where feasible, to plant fish in natural habitats. For young salmon this means in shallow rapids with gravel to rubble bottom rather than in deep pools.

(6) *Eels a danger.* Eels feed voraciously on newly-planted underyearlings. Therefore, planting sites should if possible be located away from areas of eel concentrations. Areas of large boulders and rubble in moderately swift water and pools are places where eels tend to be abundant. Eels are abundant in Bay of Fundy salmon streams, but apparently not nearly so plentiful in Gulf of St. Lawrence salmon streams. No generally feasible means of controlling eels has so far been devised.

(7) *Return of adults.* The value of hatchery-reared stock, derived from other streams, for providing adult salmon to the stream planted, needs further measurement. Hatchery-reared stock do, however, contribute to sea fisheries, even far distant from the stream of planting.

Acknowledgments

Hatchery stock was supplied and delivered on the requested dates to designated points, by the Fish Culture Branch of the Department of Fisheries. Throughout much of the work I was able to call on Mr. H. C. White for advice and assistance in field problems. The unstinting efforts of the Pollett field crew, headed at first by H. W. Coates and later by P. R. Graves provided much of the data on which these studies are based. I wish to acknowledge my indebtedness to all who assisted in any way.

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Number of Salmon Needed to Maintain Stocks

by

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Most salmon streams obtain the greater part of their stock through natural spawning. How many fish must enter a river in order to keep up the stock? Such information can contribute materially to wise use of our Atlantic salmon resources. The number needed will depend not only upon the size of the river, but also upon how many young fish the river can raise by reason of its suitability for salmon, the abundance of predators and so on. Useful information on this problem is accumulating from research on the Pollett River, a branch of the Petitcodiac system, N.B., and on certain tributaries of the Miramichi River. This account is in the nature of an interim report pending accumulation of more complete data.

(a) HOW MANY SPAWNERS ARE NEEDED?

Experiments on planting hatchery underyearlings (Elson, 1957a) have shown how many young salmon one particular stream could support. The Pollett River could produce only five to six two-year smolts per 100 square yards of stream bottom. Such production could be obtained by planting underyearlings at the rate of about 35 per 100 square yards. This in turn should give about "10 large" parr, i.e. over 10 cm. or four inches total length measured from tip of snout to tip of tail (Elson, 1957b) which is the number required to assure the maximum production of smolts. Small salmon fingerlings, when first taken from a hatchery and liberated in a stream, do not live quite so successfully as native, wild salmon of the same size. But when they have lived in the stream for a year or more, they are probably equally valuable for producing smolts. So the question may be stated—How many adult salmon are needed to give large parr at a rate of about 10 per 100 square yards?

Studies are now being made of the numbers of underyearlings, parr and smolts produced by known numbers of adult salmon entering a 10-mile stretch of the Pollett River. The number of eggs brought into the stream is of more importance than the number of fish bringing them. Pollett salmon, most of which are grilse, weigh on the average, about $4\frac{3}{4}$ pounds. The number of eggs carried by female salmon tends to be in proportion to the weight of the fish. Pollett salmon carry 800 per pound of live weight. Hence it is useful to think in terms of the total weight of female salmon in the river, rather than their total numbers. In general, sex ratios and spawning habits of salmon are such that there tends to be a sufficient number of males for the females. The results which have accumulated from these Pollett observations to date are summarized in Table I.

Table I

Underyearling and pre-smolt parr produced from known quantities of adults entering a 10-mile section of the Pollett River (25 yd. wide) based on seining in the same 10 sample areas each year. (a) Five to 15 per cent of large parr in the Pollett River are two-year-olds. This, or the limits of accuracy for seining could cause the discrepancy in the survival of underyearlings to parr.

Total weight of adult females		Potential egg deposition @800 eggs/lb. of female		Underyearlings in 1st summer		Large parr in 2nd summer		
Year	Pounds	Total number	No. per 100 sq. yd.	No. per 100 sq. yd.	Survival from eggs	No. per 100 sq. yd.	Survival from underyearlings	eggs
1953	210	168,000	38.6	2.2 (a)	6%	2.3 (a)	100%	6%
1954	390	312,000	71.7	5.9	8%	3.2	54%	4%
1955	310	248,000	57.0	4.0	7%	(in '57)	—	—

Using the results shown in this table, we can calculate that to get the 10 large parr needed in the Pollett for maximum smolt production will require, at the average survival rate of five per cent, potential egg deposition at a rate of about 200 per 100 square yards. This means about 44 pounds of female salmon (say 10 female grilse or four larger hen salmon) per mile of stream 10 yards wide. This is a general rate for the stream as a whole, not just for nursery areas or spawning beds.

In 1956 the average potential egg deposition in the same area was 252 eggs per 100 square yards. This last spawning will therefore provide a good test for the above hypothesis.

(b) DO MARITIME SALMON STREAMS RECEIVE ENOUGH STOCK?

There is strong public opinion that the Maritime salmon resource could be greatly increased by providing more very young stock, whether by legislating for greater spawning escapement, or by providing for greater distribution from hatcheries. The Miramichi is frequently referred to as a stream which should receive such benefits. For several years now, measurements have been made of the adult salmon runs into two Miramichi tributaries, and of the resulting populations of young salmon. The Northwest Miramichi has about 70 miles of effective salmon rearing water, which averages about 25 yards wide; the Dungarvon has 50 miles, and a similar width. Examination of adult salmon runs has shown the average size of the fish and the proportions of males and females. Records of the Fish Culture Branch of the Canadian Department of Fisheries show that, in general, as for Pollett fish, about 800 eggs are carried for every pound of female salmon. From this information it is possible to estimate the number of salmon eggs brought into these two streams—the potential egg deposition. The average annual figures are, for the Northwest Miramichi nearly $7\frac{1}{2}$ million eggs and for the Dungarvon nearly $4\frac{1}{2}$ million.

In Figure 1 potential egg deposition can be compared with resulting populations of young salmon as they advanced in age. All measurements are in terms of average numbers per 100 square yards of stream bottom. The values for young fish were determined by seining with electrofishing in several sample areas of each stream.

Tests have shown that the population figures for the sampling areas can be trusted to within about 20 per cent, ofter 10 per cent. Minor discrepancies in the figures given can be attributed to such error in counting the fish, but the general trends can be regarded as well established. For the Miramichi, nearly all small parr (10 cm. and under) are yearlings and over 90 per cent of the large parr (over 10 cm.), which will become smolts the following spring, are two-year-olds (Elson 1957b). For the diagram, parr have been allocated to years of egg deposition on the basis of size. Age analysis of samples, from studying scales, will doubtless result in minor corrections to the data.

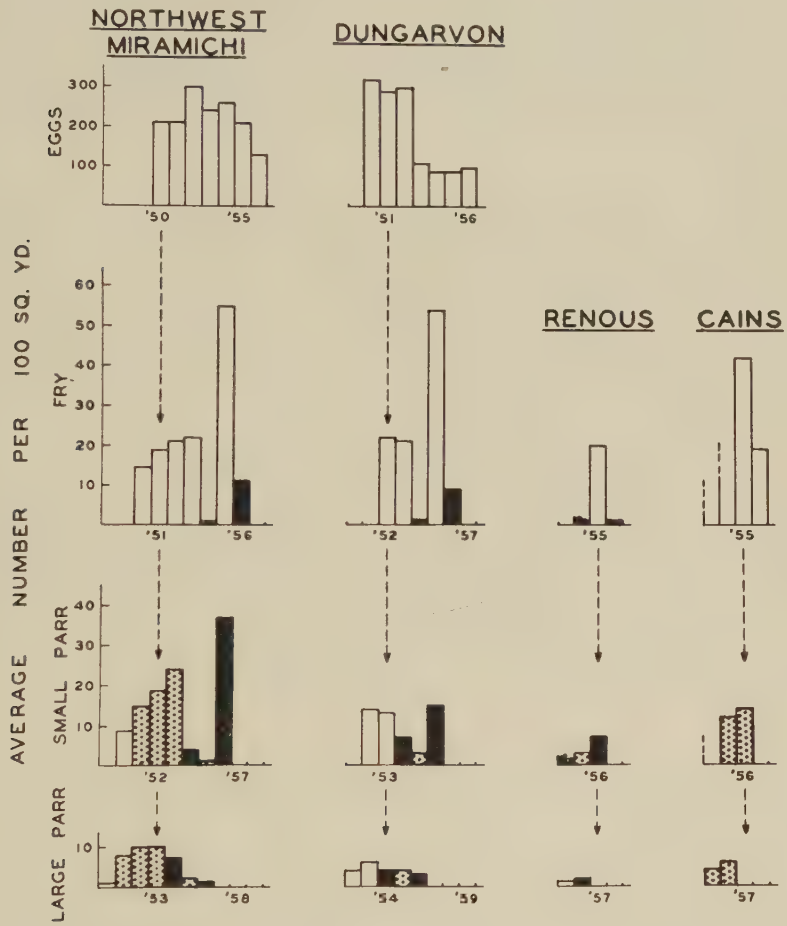

Figure 1.—Abundance of young salmon of various stages found in Miramichi streams by systematic population studies. Vertical arrows (↓) indicate survival between different stages of one year class. White columns (□) indicate abundance under natural condition. Dotted (⁝⁝) and black columns indicate abundance of groups affected by merganser control. Black columns (■) indicate abundance of groups subjected to DDT spraying as well as bird control.

Recall that in the Pollett River 10 large parr per 100 square yards were required to assure maximum smolt production. In the Northwest Miramichi similar numbers of large parr resulted from spawnings in 1949 and 1950 (Fig. 1). These two groups

received full benefit of merganser control; earlier groups did not and later groups were reduced as a result of spraying the drainage basin with DDT against an epidemic of spruce budworm (Kerswill and Elson, 1955). However, the two groups do provide evidence that the Northwest was then receiving a good supply of young stock. On the Dungarvon, full production of large parr was not realized in the absence of merganser control. However, underyearlings were as abundant as on the Northwest. Under natural conditions, potential egg deposition at a rate of 300 per 100 square yards did not produce many more underyearlings (fry) in these two streams than did potential egg deposition at 200. (Compare Northwest and Dungarvon in 1952 and Northwest in 1950 and 1951, in Figure 1.) Such a condition carries the implication that a potential egg deposition of 200 eggs per 100 square yards did not limit the production of young salmon in these streams. The Renous and Cains Rivers carried just as good stocks of underyearlings. (Fig. 1). This evidence indicates that the Miramichi has recently been receiving all the young stock that it can rear to more advanced stages.

How does the potential egg deposition in these streams compare with the calculated requirement of 200 eggs per 100 square yards made for the Pollett? The average for the Northwest has been about 235 and the Dungarvon 200; the weights of female salmon received by these Miramichi tributaries are respectively 52 pounds and 44 pounds per mile of stream 10 yards wide in comparison with the 44 pounds calculated to be required for the Pollett. There is some possibility that the Miramichi may not actually require as many eggs per 100 square yards as the Pollett in order to have the 20 underyearlings apparently necessary to give highest production of smolts. For one thing, eels have been found to prey on both salmon eggs and alevins still in the redds, as well as on older stages. But eels are only from one-tenth to one-twentieth as abundant in the Miramichi as in the Pollett. The average *natural* survival rate from eggs to fry found for the Miramichi (8 percent) was just as good as that found on the Pollett (7 per cent) with *very light* spawning. A very light spawning should give a maximum survival rate, since no excess over actual requirements is involved. In the Miramichi area, the lighter spawnings observed *did* give the best survival rates so some excess over actual requirements may well have occurred in the heavier spawnings.

During the period of these observations the Miramichi has received some plantings of underyearlings salmon each year. The Northwest Miramichi, has been planted with underyearlings at an average rate of 25 per 100 square yards for the whole stream. All plantings were actually placed in the lower 25 miles, which are accessible for hatchery distribution. Young salmon were most abundant in the upper 40 miles. On the Dungarvon, plantings provided underyearlings at an overall rate of six per 100 square yards; but all were liberated in the lower five miles of the stream because above this it is impractical to reach the river with hatchery products. Again, young salmon were relatively much more abundant in the upper part of the river. Thus the largest parts of these streams were not available to hatchery stocks (Elson 1957a). Most of the young stock must have come from natural spawning.

It does appear that several Miramichi streams have, in recent years, received sufficient young stock, mostly native, to produce many more smolts than they are now

doing. In fact, natural spawning has been sufficient to give maximum smolt production, if judged by standards developed on the Pollett River. It is hard to see how such streams could, *under normal conditions*, use to advantage more brood stock or hatchery products than they have recently been getting.

With the information at present available the best figure for the number of adult salmon required to maintain stocks can be set at "between 40 and 50 pounds of adult females per mile of stream 10 yards wide".

However, as shown in Figure 1, these young stocks are now seriously reduced as a result of spraying the adjacent forest with DDT. This chemical kills a high percentage of the young salmon. If spraying is to continue, natural spawning alone cannot provide a remedy since the young fry are most susceptible of all to the spray. Carefully planned use of hatchery stocks seems to be the one way of getting better production under these circumstances.

Acknowledgments

Much of the data used has been collected through the untiring efforts of the Pollett field crew, consisting of P. R. Graves, H. P. Barchard, L. MacFarlane and A. G. Steeves, of Elgin, N.B. Others assisted this group in the Miramichi seining studies. Dr. C. J. Kerswill provided data on Miramichi salmon runs. To these and all others whose assistance facilitated the work I extend my thanks.

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The Role of Hatcheries in Assuring Maritime Stocks of Atlantic Salmon

by

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The abundance of Canadian Atlantic salmon as measured by records of catches has varied a good deal from time to time, even in "the good old days." Man has attempted to reinforce the stocks of these fish by artificial propagation of the young. Canada was one of the foremost countries in bringing such culture to a high stage of development. Our system for rearing young salmon and distributing them in suitable streams is one of the largest in the world.

Extensive distribution of hatchery-reared salmon in eastern Canada began about 1875. The early distributions were followed by large increases in the catches of salmon after the expected intervals, and in the proper districts (Wilmot, 1885). These increases were very welcome, following, as they did, right on the very lowest commercial salmon harvest on record, in 1881 (Fig. 1). Hatchery distributions continued to increase until they reached about 25,000,000 fingerlings yearly in the 1930's. Since then they have been reduced to around 10,000,000 to 15,000,000.

RELATION OF HATCHERY DISTRIBUTIONS TO CATCHES:

Have these widespread plantings had the notable effect on salmon harvests that was predicted in the 1885 report? If so, years of heavy planting should have been followed in due course by particularly good catches of salmon, and smaller plantings by smaller catches. For the Maritime Region (Cape Gaspé to the St. Croix River) most commercially caught salmon spend three years in rivers and two years at sea. The common interval from planting to harvest is therefore five years.

The sizes of hatchery distributions and corresponding catches in this region have been arranged diagrammatically in Figure 2. In the middle row vertical bars representing hatchery distributions between 1907 and 1947 have been arranged in descending order of magnitude. In the lower row bars representing commercial catches made *five years later* are arranged directly *under* their corresponding distribution bars. There is no clear resemblance between the patterns formed by the two different rows of bars. The conclusion seems to be that the contributions of hatchery plantings to the general salmon catches have not been large enough to show through the natural variations in these catches.

Hatchery distributions might be compared with commercial catches made *one year before* the distributions. Such catches represent, more or less, the availability of parent stock to the hatcheries. These catches are shown in the upper row directly

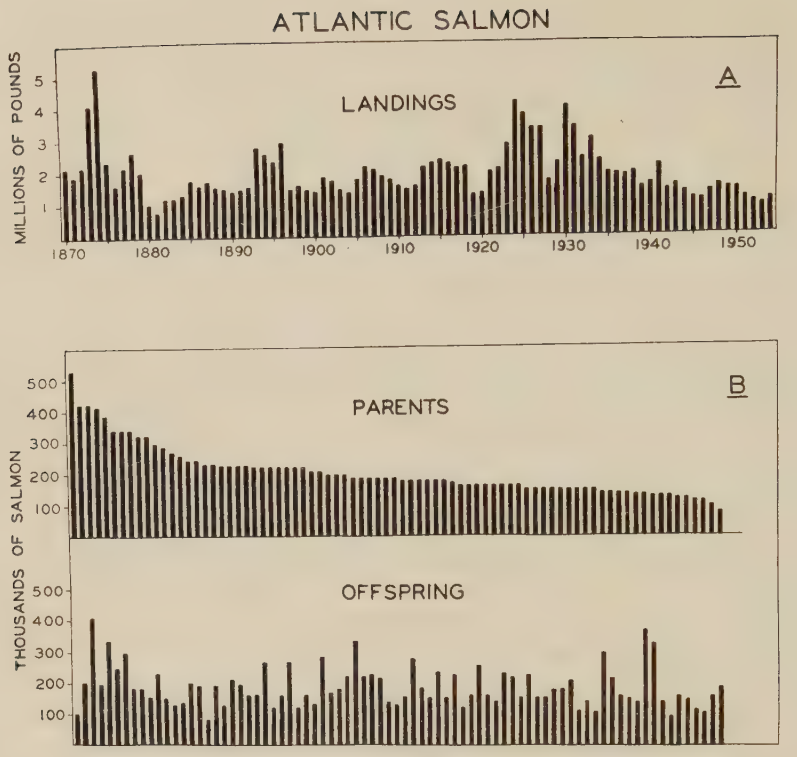

Figure 1.—Commercial landings of Atlantic salmon from the Gulf Area of the Maritime Region for 85 years. A. Annual landings in chronological order. B. Same catches plotted as numbers of 10-lb. salmon. Upper panel: numbers of parents in the first 79 years arranged in order of magnitude. Lower panel: numbers of offspring caught six years later, drawn directly below corresponding parent catch. There is no evidence of any relation between the size of catches from parents and the size of catches from their offspring. (Reproduced from Elson, 1955)

above their corresponding hatchery distribution. There is, in fact, a tendency for hatchery distributions to be larger in the years following abundant harvests of salmon. The relationship is obscured somewhat by a few particularly good catches; but the upper row of bars also tends to slope downward from left to right. It is quite logical that the hatcheries should be able to collect more eggs in years when mature salmon can be caught more readily. This is apparently what happened.

Both of the relations discussed above have been tested mathematically and the conclusions presented found to be valid.

As can be seen in Figure 1, there is no clear-cut relationship between the amount of parent salmon caught in one year and the amount of their offspring caught six years later (Elson, 1955). This can be interpreted as meaning that having a great many more salmon spawn in one year does not necessarily lead to an abundant catch of their offspring. Apparently naturally produced increases of young often do not show up in later catches. It should not be surprising, therefore, that artifically produced, smaller increases in young are not apparent either.

Thus the evaluation made in the 1880's of possible hatchery contributions has not been substantiated by later experience.

WHAT OUR HATCHERIES CAN CONTRIBUTE.

The fact that hatchery contributions cannot be identified by their effect on catches does not mean that they are not of value. In the last century practically nothing was known about the usual fate of planted fish. In the past quarter of a century considerable information on this subject has been collected. In those early years people

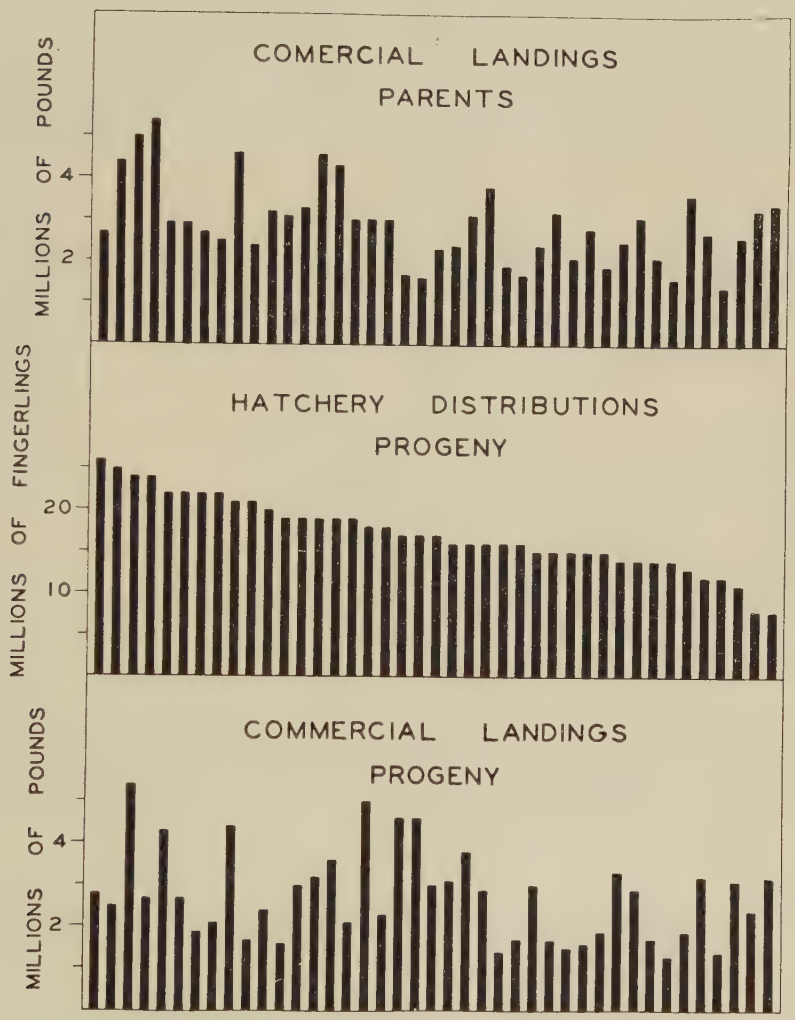

Figure 2.—Hatchery distributions of young Atlantic salmon arranged in order of magnitude (middle row) for comparison with commercial landings one year earlier (above) and five years later (below). There is a similarity of trend between earlier catches and distributions: this probably reflects availability of parent stock to hatcheries. There is no similarity between the trends for distribution and catches five years later when the planted fish should have made their biggest contribution to fishing: this indicates that hatchery contributions were not large enough to outweigh natural causes of fluctuation.

were pleased or worried over the status of salmon stocks according as recent catches had been good or bad (Perley, 1852) but there is no record of any attempt to estimate the total extent of Maritime salmon stocks. Now, as a result of researches made in the last 25 years, at least a rough estimate can be made. Thus it is now possible to place a better measurement upon the contribution which our hatcheries can make.

For this the first question to be asked is: How many mature salmon could be produced from 15,000,000 young salmon liberated each year by the hatcheries? It has been calculated on experimental evidence (Elson, 1957a) that with careful planning and management up to 15 per cent of hatchery-distributed underyearling salmon can be expected to survive to the smolt stage. Under adverse conditions the survival rate is liable to be only a fraction of this amount, perhaps around three per cent. Seaward-migrating smolts have been counted and marked in a number of instances, and their numbers compared to the numbers of returning adults. From these and similar studies it is found that, on the average, about eight per cent of the smolts (Table I)

Table I

Estimated survival rate of salmon marked as descending smolts based on reported returns to fisheries and counting fences in rivers; except Hayes (1953), which is based on estimates of total smolt production and total salmon associated with the river.

Place	Author	Survival rate
		%
LaHave, N.S.	Hayes, 1953	17
Margaree, N.S.	Huntsman, 1941	over 2
Miramichi, N.B.	Kerswill, 1957	5
Moser River (Mill Brook), N.S.	White, 1940	over 10
Moser River (main stream), N.S.	White, 1940	over 5
Moser River (Mill Brook), N.S.	White, 1941	10
Moser River (main stream), N.S.	White, 1941	9
Moser River (main stream), N.S	White, 1943	over 9
Apple River, N.S.	White and Huntsman, 1938	over 3
Mean survival rate and its standard error		8 ± 1.5%

survive the rigours of life in the sea and return to fisheries and rivers as mature salmon. Considering these survival rates, the yearly contribution of hatchery fingerlings could conceivably add about 180,000 adult salmon to the stock available for fisheries and spawning. This amount is roughly equivalent, in numbers, to the total take by commercial fisheries in the Maritime region.

MAGNITUDE OF SALMON STOCKS IN THE MARITIME REGION

1. Direct estimate from fisheries.

In order to evaluate the hatchery contribution we should develop at least a general idea of the size of the total stock. Our impressions of abundance are usually obtained from the numbers of salmon caught in fisheries. But how is catch related to actual abundance? There have been a number of studies in which salmon caught in nets, at sea or along the coast, have been tagged and immediately released again. Subsequent recapture of some of these fish leads to our best available estimate of the total

salmon stock. Table II gives the results from various areas. Applying the average value for recaptures (27 per cent) it appears that the combined commercial and sport fisheries of the Maritime region remove a little over one quarter of the salmon stocks available to the area. In recent years the commercial catch has amounted to around

Table II

Atlantic salmon tagged and liberated from commercial fisheries and recaptured in both commercial and sport fisheries.

Place of tagging	Number tagged	Total recaptures	Author
		%	
Petit Gaspé, P.Q.	100	38	Belding and Prefontaine, 1938
Sept Isles, P.Q.	80	9	
Rivière Nabissippi, P.Q.	43	28	
St. Augustin, P.Q.	63	6	
St. Paul P.Q.	150	29	
Port aux Basques, Nfld.	599	13	
Miramichi, N.B.	411	18	
Margaree, N.S.	758	13	Hayes, 1948
Margaree, N.S.	416	8	Hayes, 1949
LaHave, N.S.	192	28	Hayes 1953
Margaree, N.S.	100	25	Huntsman, 1939
Margaree, N.S.	161	26	
Margaree, N.S	267	25	
Saint John, N.B.	102	68	Huntsman, unpub.
Lorneville, N.B.	100	71	
Dipper Harbour, N.B.	102	31	
Total number tagged	3,644		

Mean rate of recapture and its standard error 27 ± 4.5%

150,000 salmon per season. The sport fishery in this region has been estimated to take 55,000 fish yearly, of which about one half are grilse (Kerswill, 1957). The grilse must be considered because they represent young stock which has survived to maturity just as much as larger salmon do. The total catch thus amounts to about 200,000 fish. If, as indicated in Table II, this is about one quarter of the available stock, there must be in the vicinity of 1,000,000 salmon available to the Maritime region. The rates of recapture listed indicate that it is unlikely that the total stock falls as low as 500,000 or exceeds 1,500,000 salmon in any one year.

2. Stock size at various stages

In order to appraise the usefulness of hatcheries, it is helpful to have estimates of the salmon stocks at various stages from eggs to adults. Estimates of this kind can be obtained from our data by using a slightly different chain of facts. The total catch by fisheries, say 2,000,000 pounds, is still used as the starting point. Also the proportion (27 per cent) that this forms of the total stocks as indicated by tagging results must be considered. Now let us assume that more fish are lost to seals, sharks, poachers and other causes of deaths in the sea and rivers, to the extent that only half of the total mature stock in the sea is left in the streams for spawning. As a matter of fact, Hayes' data for the Margaree (1949) shows not over 58 per cent of the counted,

available fish for the system being thus available for spawning. (He counted fish removed by the commercial fishery, fish entering the river and fish removed by anglers.) Using the 50 per cent figure, we should have close to 4,000,000 pounds of salmon available for spawning in Maritime region rivers. In general, half of these would be females. Female salmon carry about 800 eggs per pound of body weight. The survival rate from eggs, brought into one particular river, to fingerlings the following summer has been established as about 5 per cent when there is no excessive spawning (Elson, 1957b). Using these figures, Maritime salmon streams, as a whole, are now receiving natural stocking at the rate of about 80,000,000 salmon fingerlings per year. Information now accumulating indicates that under favourable conditions, which include protection from excessive predation by mergansers, one-quarter or more of these fingerlings can survive to the smolt stage. These smolts, granting an 8 per cent survival rate over their sea life (Table I) would contribute a little over 1,500,000 salmon to the stock available for fisheries, spawning, etc. This second estimate is of the same general order as that obtained by a slightly different chain of thought, above.

The tagging studies referred to in Table II were made in areas of relatively important fisheries; and of course only salmon which had already entered the fisheries could be tagged. There are considerable numbers of salmon associated with small streams where fisheries are less intense. There are also many salmon which apparently do not reach fishery areas during open seasons; for example, the extensive autumn runs of the Miramichi system. To the extent that the tagging studies take no account of such fish the estimate of total stock given above is too low. However, plans for reasonable exploitation and conservation of the stocks based on low estimates are quite unlikely to damage our salmon resource.

Discussion

The potential value of the annual hatchery contribution might be evaluated on the basis of (1) 15,000,000 hatchery fingerlings added to the native stock of around 80,000,000 native fingerlings; or (2) 180,000 mature salmon added to the sea stock of about 1,000,000 fish; or (3) 50,000 salmon added to the 200,000 taken by fisheries. However assessed, the potential contribution seems to be of the general order of one-fifth to one-quarter of the present stock.

An addition of 500,000 pounds (commercially caught salmon average about 10 pounds weight) to Maritime region catches is a valuable contribution. But, spread over the entire region, it could scarcely be identified in catch statistics of a fishery which has fluctuated from under 1,000,000 to over 5,000,000 pounds per year during the last 80 years. This explains, at least in part, why the value of hatchery contributions does not show in such an analysis as is illustrated in Figure 2. However, an additional catch of 500,000 pounds divided among a few smaller fisheries could make a very evident contribution to these.

In the same way, an increase in general spawning stock of 75,000 to 100,000 salmon would scarcely be noticed by its effect. But this is enough salmon to completely stock a number of small rivers, or even one fairly large system. As an example, an

annual run of 3,000 to 4,000 grilse and salmon combined appears to provide good angling and sufficient spawning stock in the 70-mile-long Northwest Miramichi River.

Thus Canada's hatchery system for Atlantic salmon can add a valuable amount to Atlantic salmon stocks. But even more important, it is a resource which can ensure against extinction of stocks if and when this should threaten.

The professional fish culturist, alone, is likely to have ready access to the background of facts which are necessary in order to make a sound decision about where and how hatchery stock can be used to best advantage. He must first get some clue as to why fish are scarce. Could it be simply that weather and water conditions were not right for getting the salmon into fishery areas? Or are young salmon really scarce in the nursery streams? If so, are they scarce, from the very youngest stages up, or only the older stages? What are the conditions that face the different stages of young in any particular stream? To be most effective, hatcheries must be able to add fish to replenish the stage at which native fish are scarce in the stream. Hatcheries are not designed to remedy shortages by supplying excessive stock in advance of depletion and regardless of the cause. These are the sort of problems that must be considered in order to get the most out of hatcheries for Atlantic salmon. Whenever well-considered answers can govern their procedures, hatcheries provide, over the years, a means of bolstering and restoring damaged fisheries; of revitalizing fisheries which have nearly or entirely disappeared; and even of creating new stocks for new fisheries. But if uninformed demands or other circumstances govern their procedures, our hatcheries can, at best, hope to add only about one quarter to the value of the general salmon harvest. No contribution of such magnitude could be positively identified in catch statistics.

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